New approaches to more efficient solar energy conversion

(QD's, High T's and Singlet Fission)

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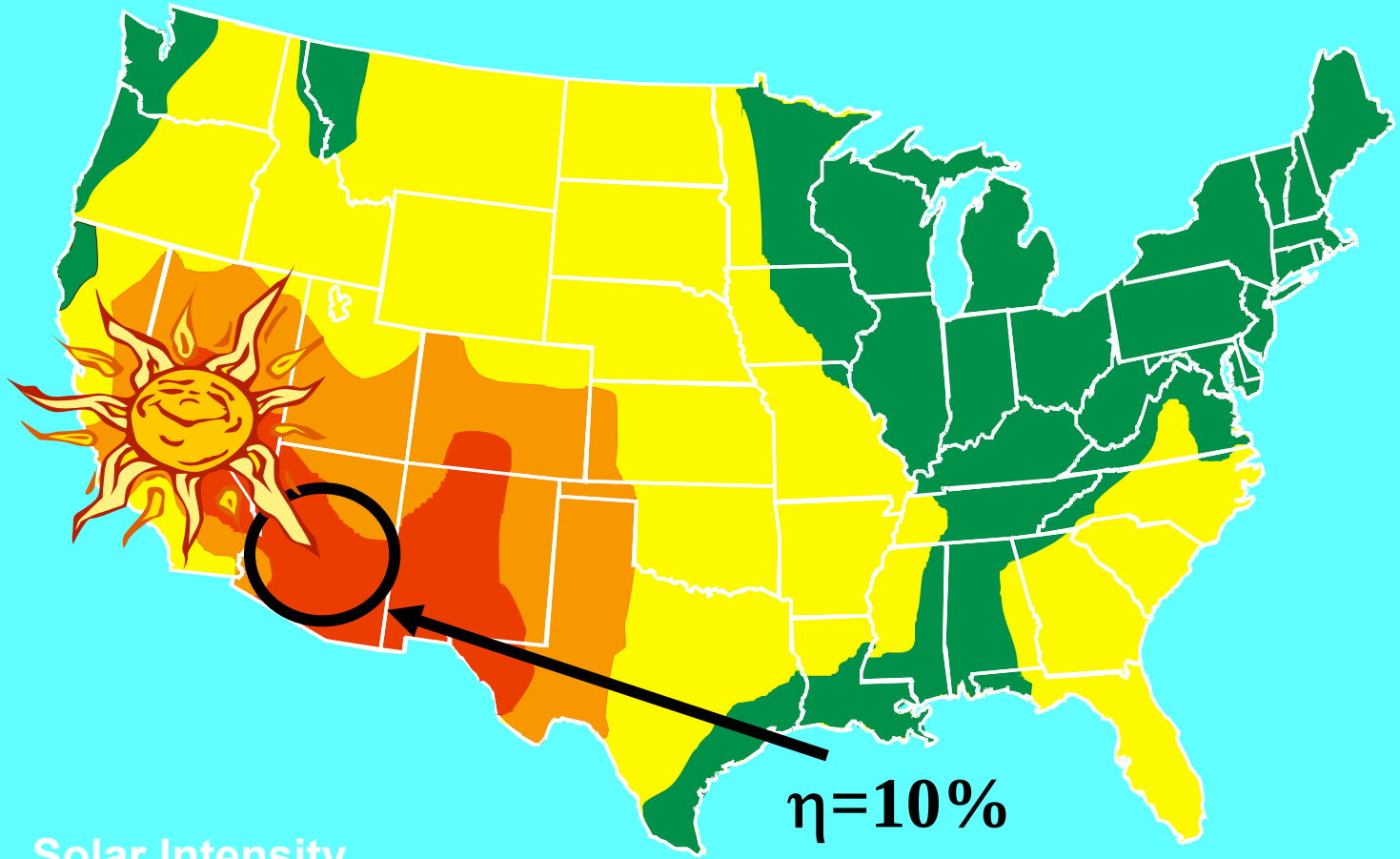
Energy Initiative

UNIVERSITY OF COLORADO AT BOULDER

The University of Colorado Energy Initiative encompasses the activities of students, faculty and staff from the entire Campus. The goal of the Initiative is to address the scientific, political, social and economic challenges of developing and implementing renewable and sustainable energy.

http://ei.colorado.edu

Available Solar Resource in the U.S.



Barriers to Utilization of Solar Energy: energy from the sun is intermittent, seasonal, regional and diffuse

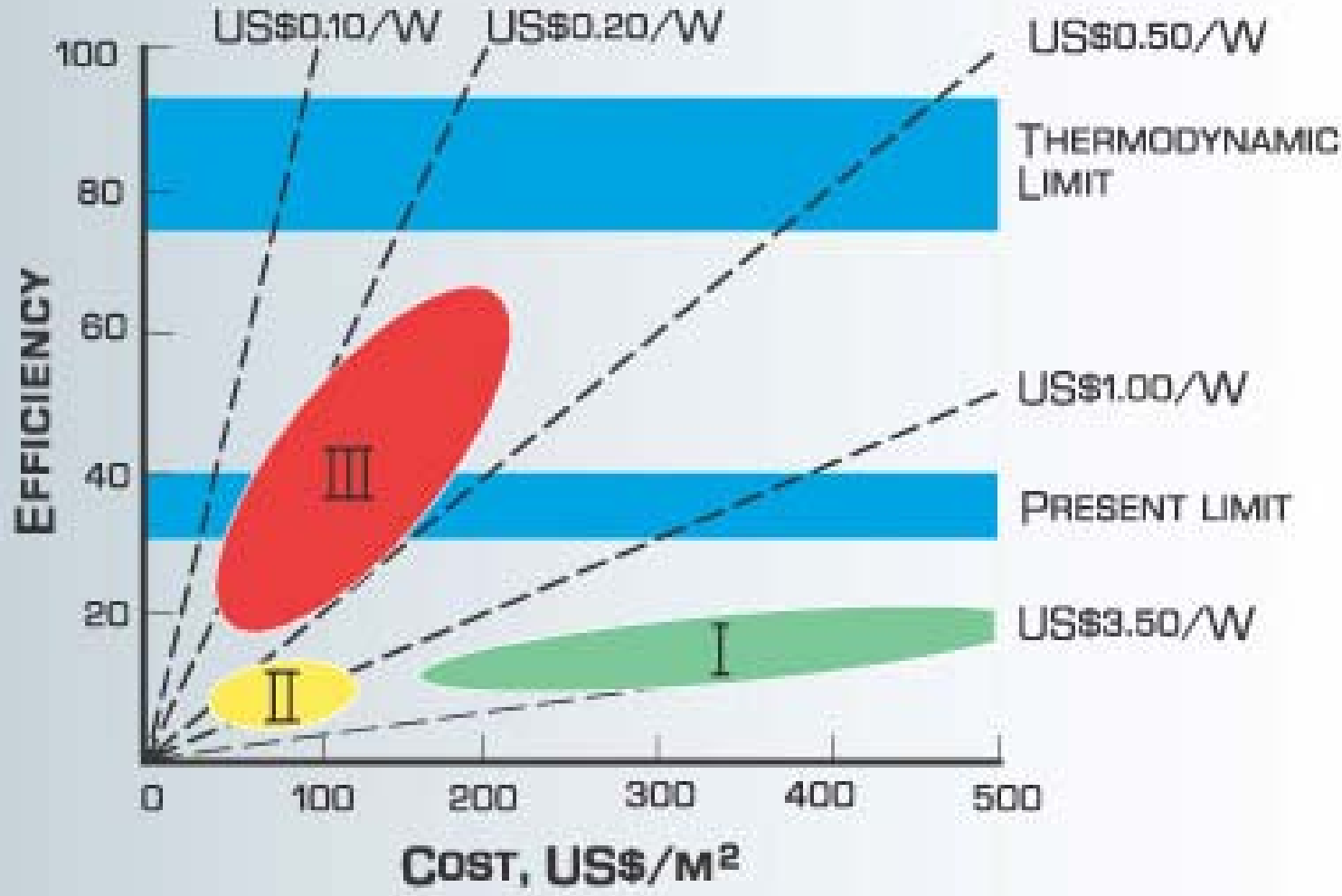
The world's largest solar power facility covers more than 1,000 acres near Kramer Junction, California. The facility can produce up to 150 megawatts of electricity, enough to power 150,000 homes. (Photo courtesy Kramer Junction Company/NREL)

1000 acres is more than
4 million square meters!

Efficiency is critical!!!

Efficiency vs. Cost for Photovoltaic Electricity

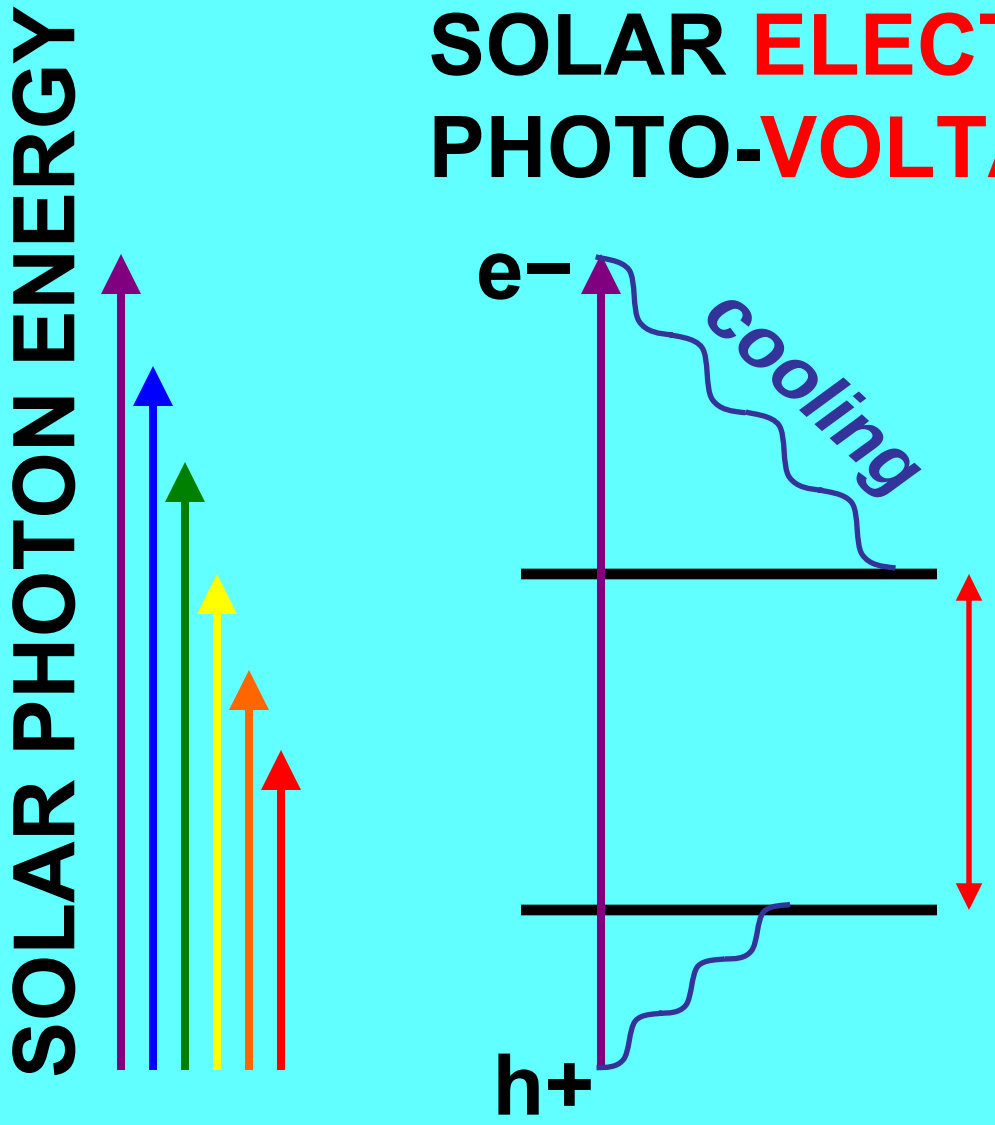
I. **1st generation PV: high quality crystalline silicon**
II. **2nd generation PV: semiconductor thin films**
III. **3rd generation PV: ???????**



http://www.pv.unsw.edu.au/Research/3gp.asp

SOLAR ENERGY

SOLAR ELECTRICITY: PHOTO-VOLTAICS (PV)



1 electron with Energy = band gap of Photo-Voltaic

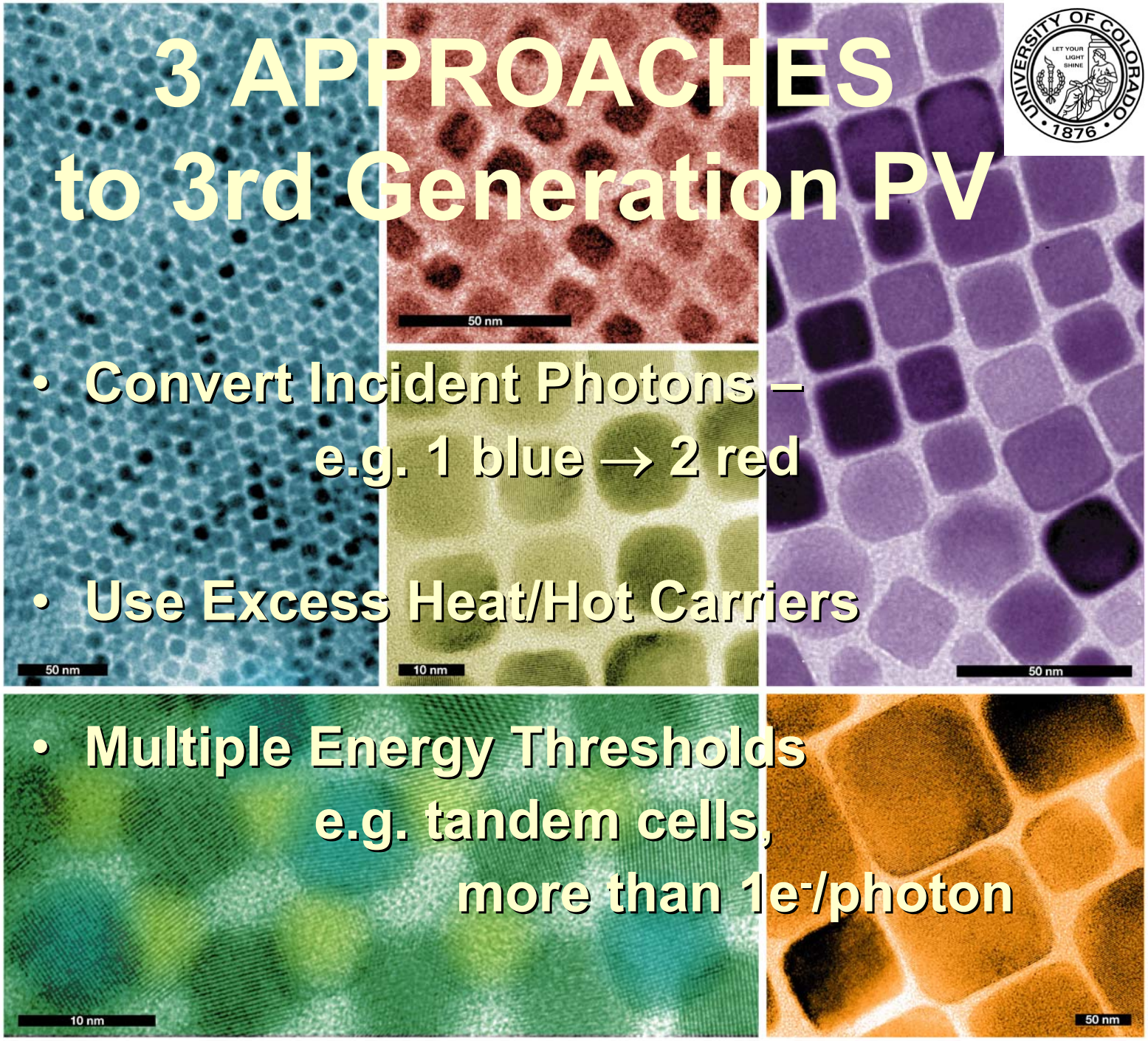
JONAS

QD's

Arrays of cubic and spherical PbTe and PbSe QDs typically ~ 6000 atoms/dot

Jonas-CU
Nozik NREL

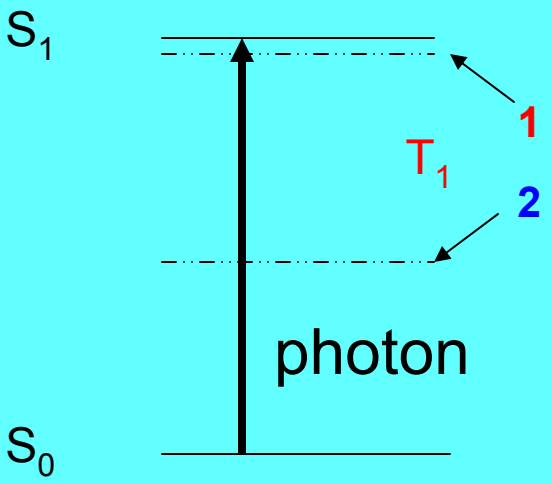
3 APPROACHES to 3rd Generation PV



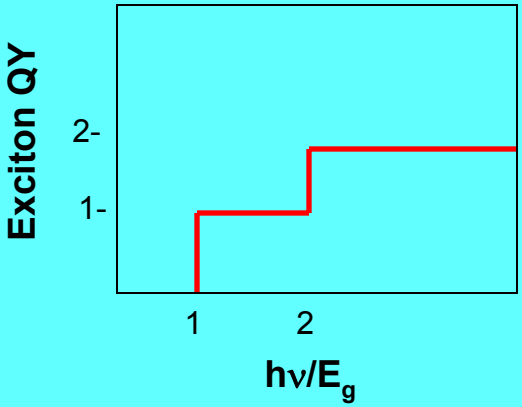
- Convert Incident Photons – e.g. 1 blue → 2 red
- Use Excess Heat/Hot Carriers
- Multiple Energy Thresholds e.g. tandem cells, more than 1 e^-/photon

Molecular Singlet Fission (Michl Lab)

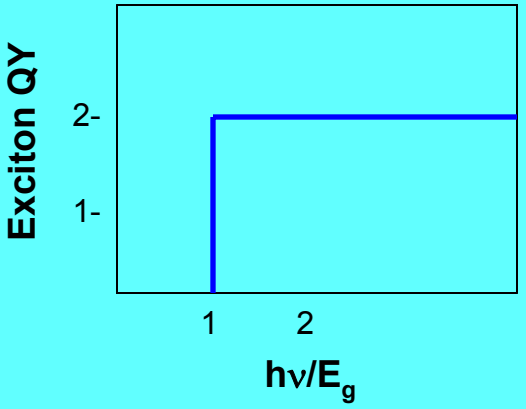
$$S+S_0 \rightleftharpoons (TT) \rightleftharpoons T+T$$



Case 1: **Exciton QY is like CM in QD's**

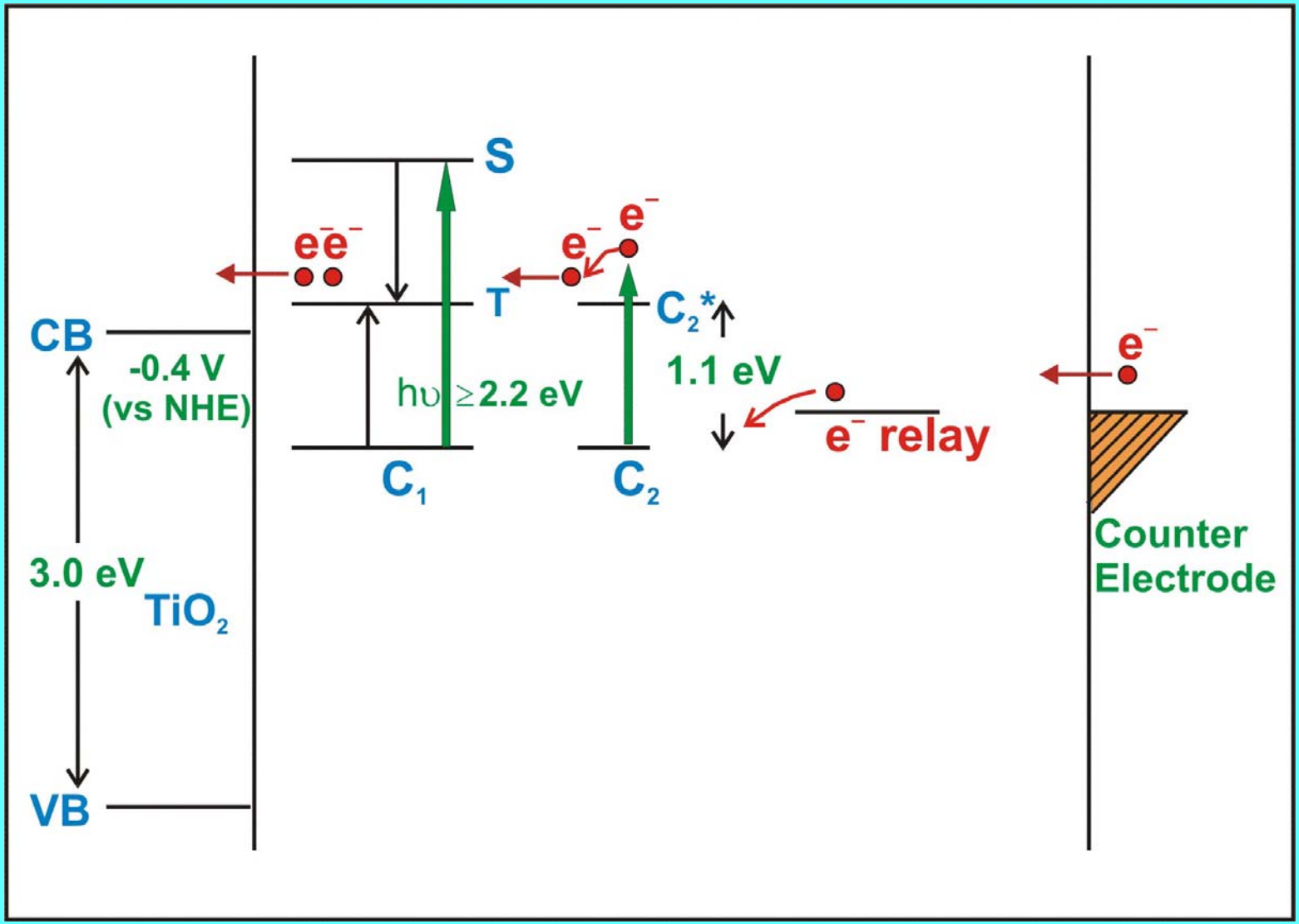


Case 2: **Tandem devices or PEC cells**

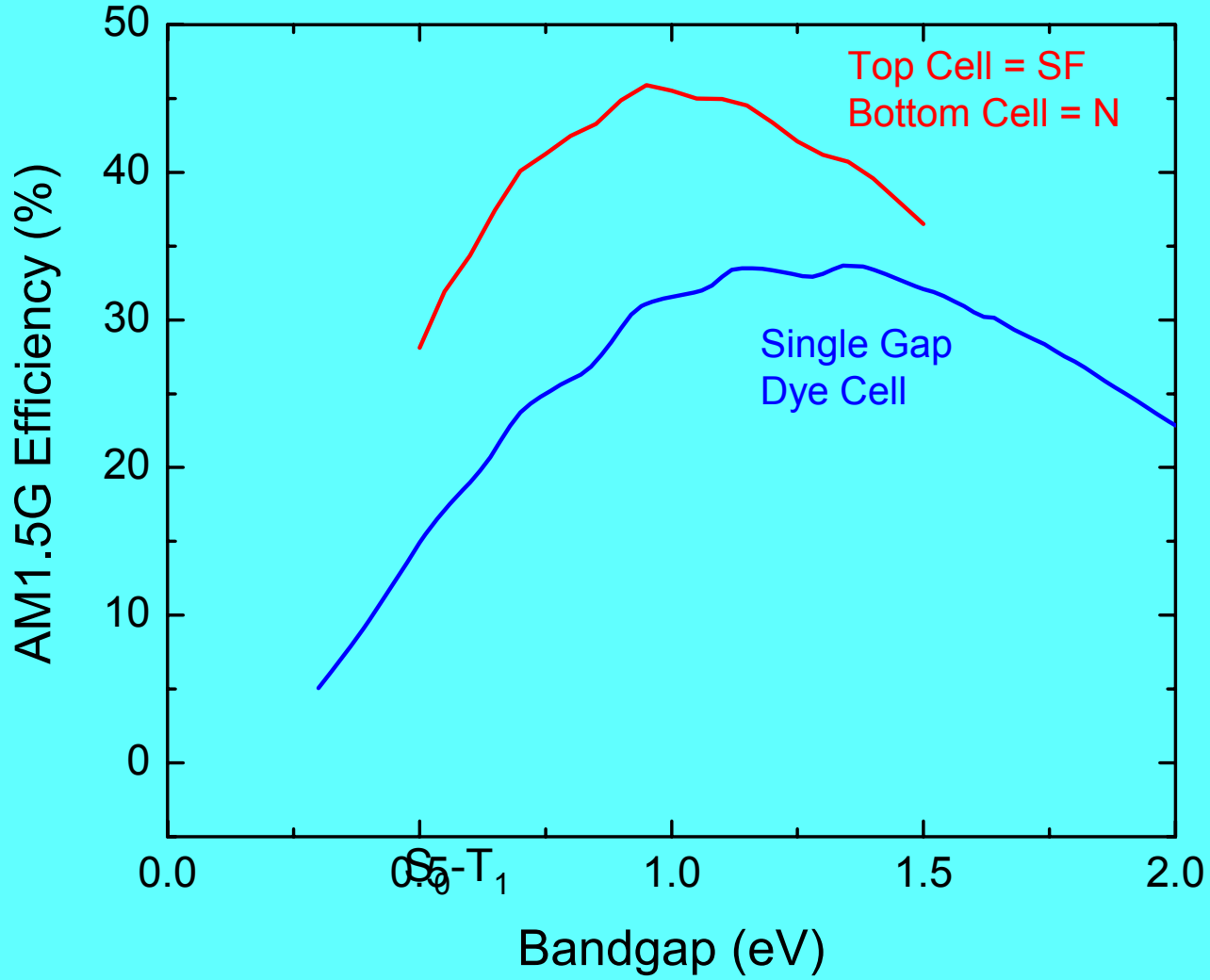


Graetzel-type solar cell (TiO_2 and molecular dye)

w/ normal & singlet fission chromophore

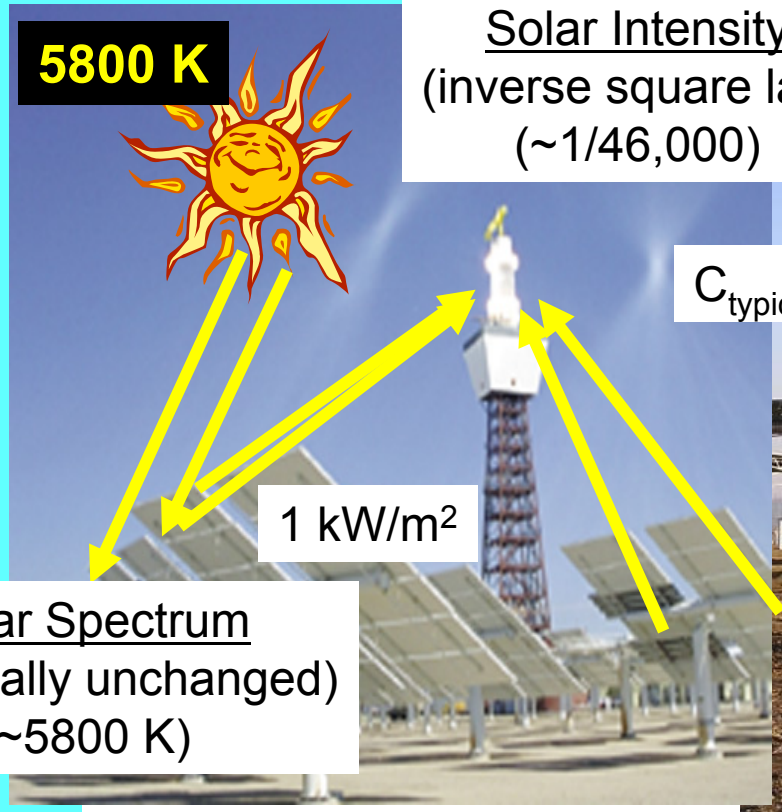


Singlet fission solar cell efficiency



High T's

Commercial Solar-thermal Central Receiver to Electricity (Seville, Spain)



Solar Intensity
(inverse square law)
(~1/46,000)

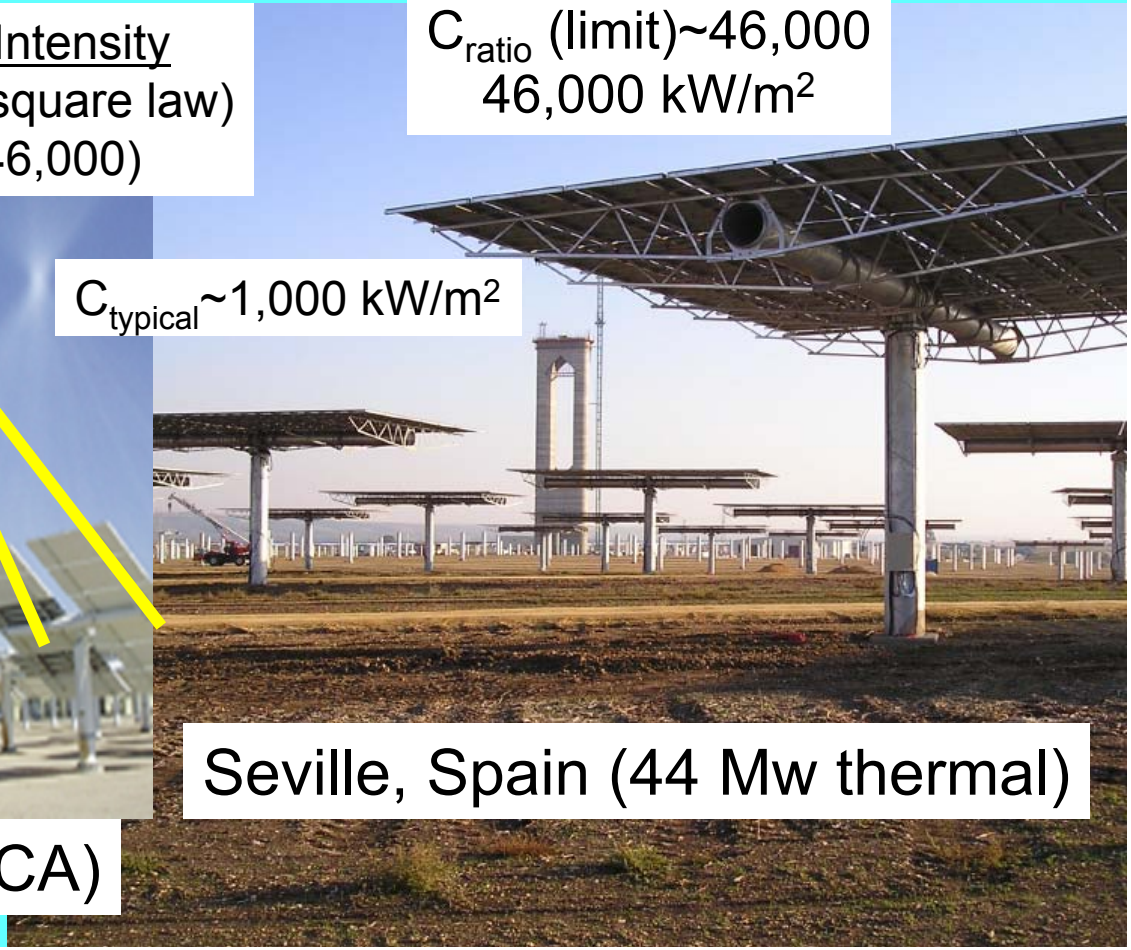
C_{ratio} (limit)~46,000
46,000 kW/m^2

$C_{typical}$~1,000 kW/m^2

1 kW/m^2

Solar Spectrum
(essentially unchanged)
(~5800 K)

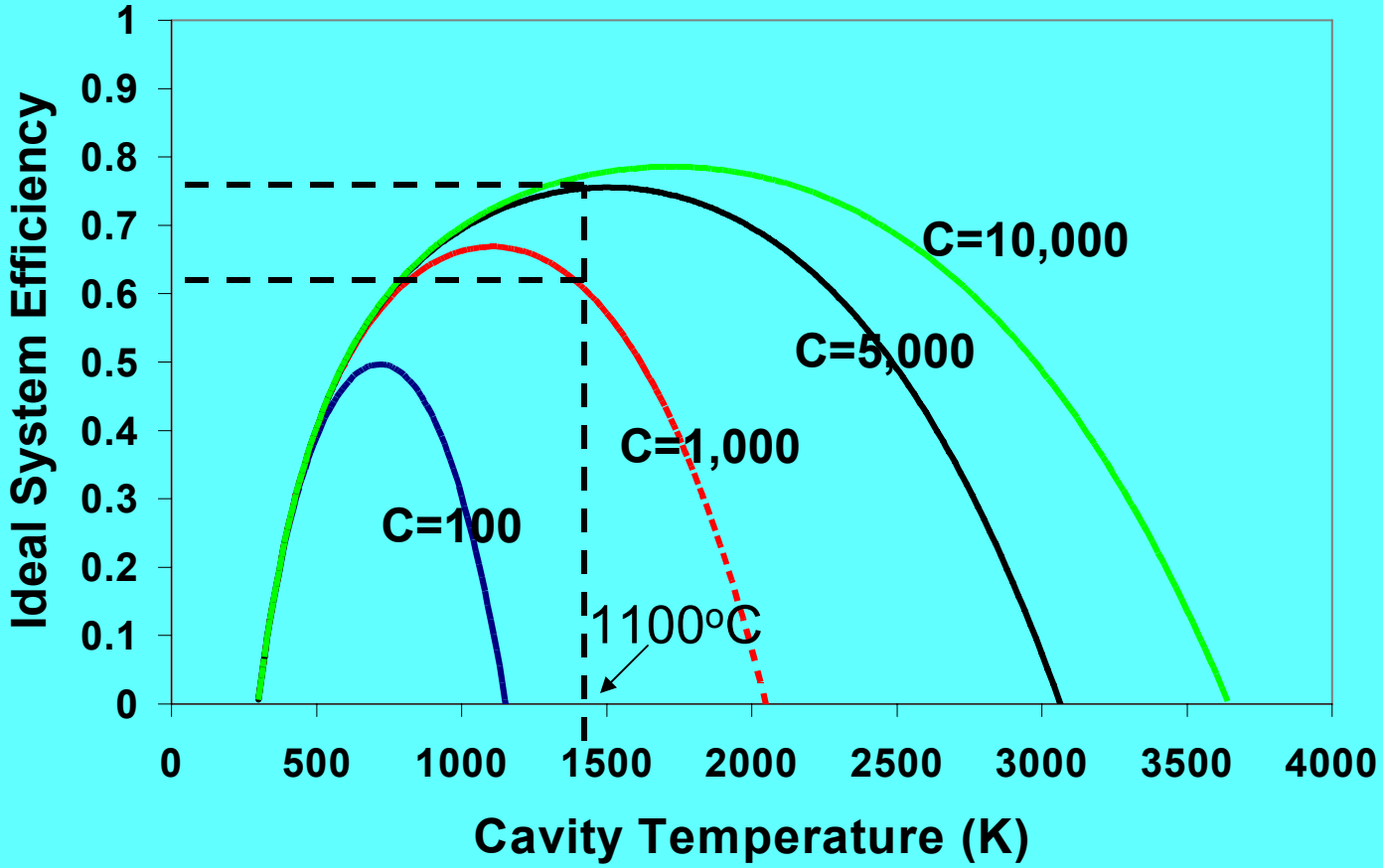
Solar II (Barstow, CA)



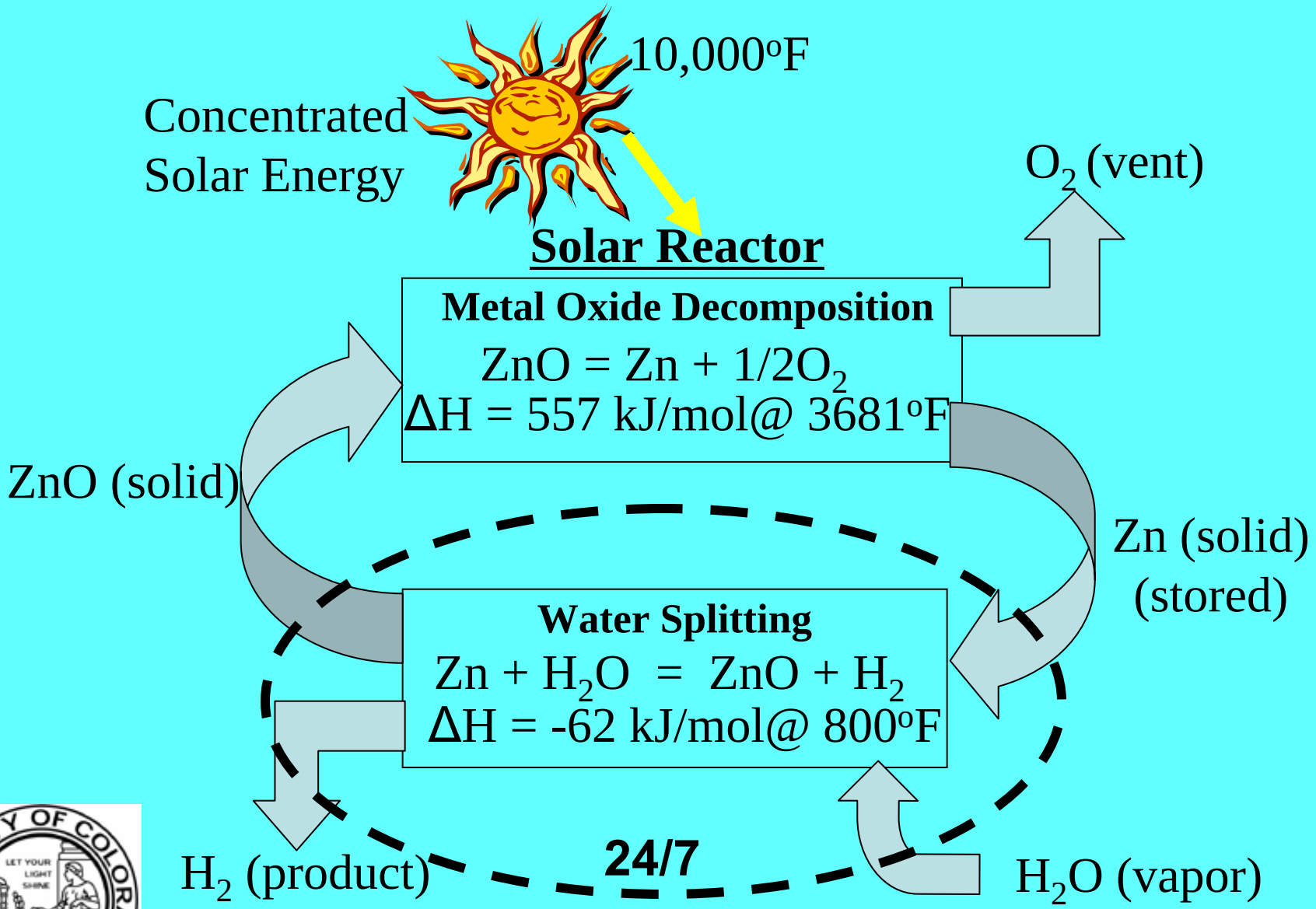
Seville, Spain (44 Mw thermal)

Ideal System Efficiency of a Solar-thermal Cavity Receiver

$$\eta_{System} = \eta_{Carnot} \times \eta_{Absorption}$$

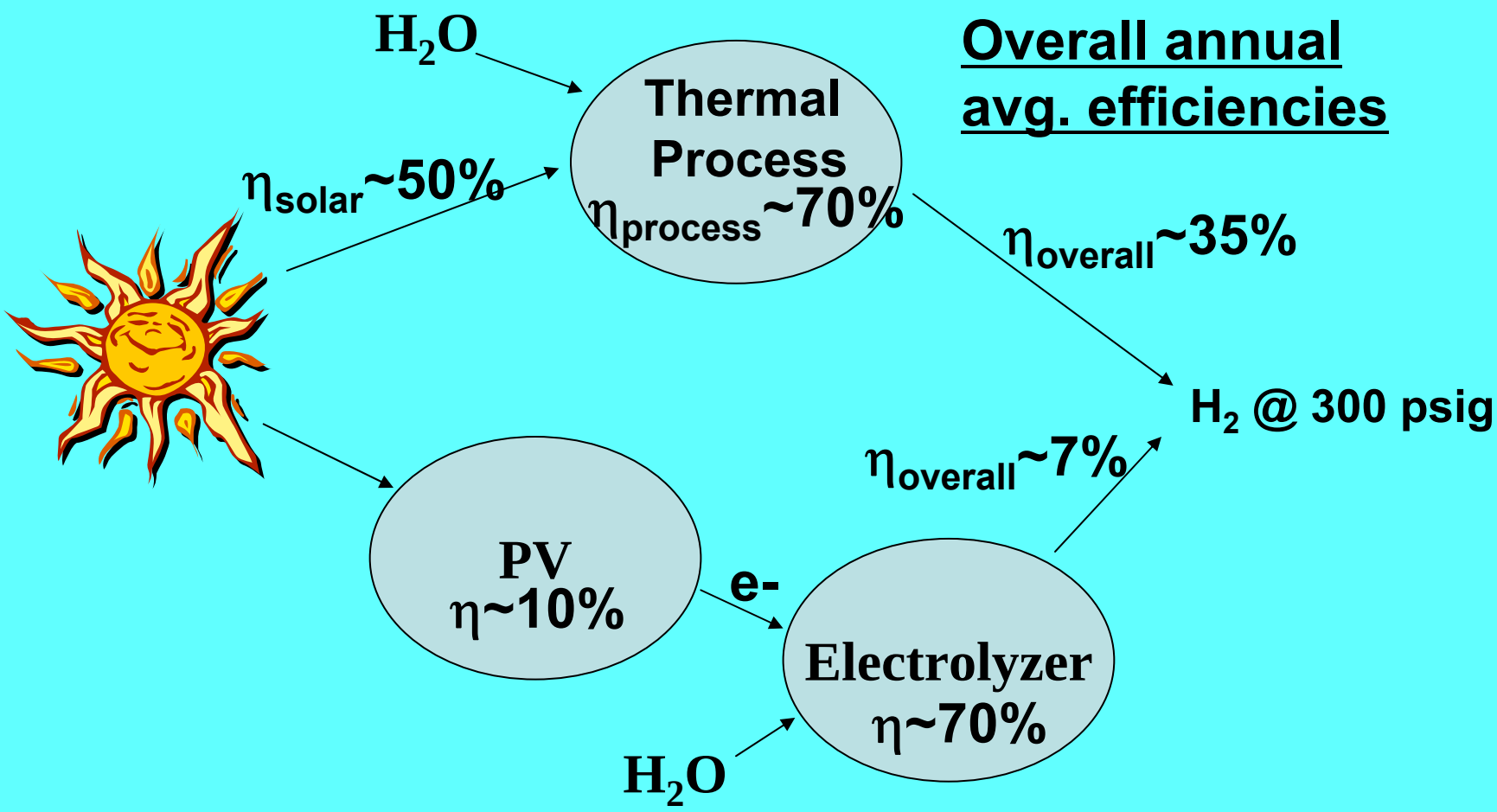


Solar-thermal Process to Split Water



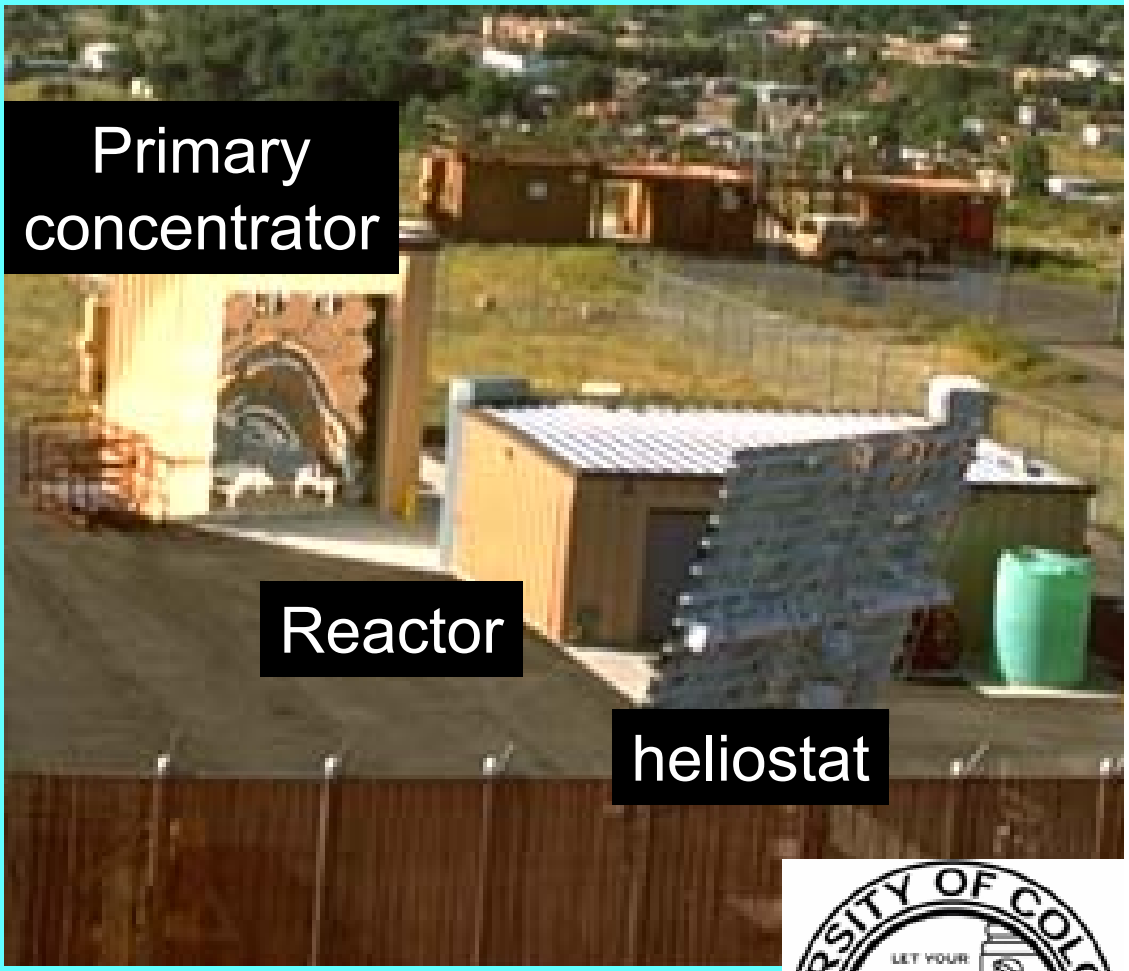
A. Weimer, Dept. of Chemical and Biological Engineering

Solar-thermal Conversion vs. PV/Electrolysis for H_2 Production (Weimer Lab)



Reduction to Practice
(10 kW Solar Furnace at NREL)

Reactor @3000°F



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Biorefinery w/ Thermochemical Conversion of Cellulose and Lignin

feasibility demonstrated in Weimer lab in last 3 months !